THURSDAY, MARCH 28, 1907.

ULTRAMICROSCOPES.

Les Ultramicroscopes. Les Objets ultramicroscopiques. By MM. A. Cotton and H. Mouton. Pp. 232. (Paris: Masson et Cie., 1906.)

THE magnitude of an object which can be rendered visible by the ordinary use of the microscope has a lower limit which is well understood and can be succinctly expressed. It depends not merely upon the construction of the instrument, but also upon the character of the light employed and upon the liquid used for immersion. The instrument should possess a large numerical aperture, which is again increased by immersion in the ratio represented by the index of the immersing liquid, the result being the scientific expression for the power of the instrument, with a given magnifying power, to resolve close lines or points. As regards the light itself, the limit of resolution is proportional to the wave-length, so that shorter wave-length implies greater power of resolution. When special light is not selected for employment, the mean value of the wave-length is 0·55 μ, where μ signifies 0·001 of a millimetre.

Taking full advantage of these principles and of the high index, 1.66, of monobromonaphthalin as an immersion liquid, it may be said that the smallest visible objects have a magnitude not less than 0·17 μ. Bodies smaller than this are called ultramicroscopic. Some plan other than the usual microscope method must be adopted in order to make their existence appreciable, and it is upon this subject that MM. Cotton and Mouton have written the very valuable and learned book before us. In it will be found accounts, not merely of their own work, which is far-reaching and in practical points highly ingenious, but also of that of other investigators in the same field.

There are two methods at present in existence, which may be called respectively that of ultra-violet light and that of diffraction in a dark field. The first method aims at taking advantage of the short length of ultra-violet wave-lengths. The sources of light are electric sparks formed between wires, which may be of magnesium, producing wave-lengths of 0·280 μ, or of cadmium, producing those of 0·275 μ, the former being more intense, the latter more homogeneous. Such waves produce no effect upon the eye, though much upon fluorescent screens and photographic plates. But they are readily absorbed by glass. Hence the media (excepting air and immersing liquids) through which they pass on their way to the fluorescent screen or photographic plate, as the case may be, must be of quartz, and those above the stage of the microscope must, to avoid effects of double refraction, be of fused quartz. Thus the whole apparatus is highly specialised. On the other hand, the rays employed being homogeneous, there is no chromatic aberration to be considered in the design of the lenses.

The image formed by the objective is again magnified by the ocular, employed in such a way as to form a second real image at the place where finally is placed the fluorescent screen or photographic plate. With such an apparatus the limit of magnitude of the objects detected would be reduced to 0·09 μ.

The second and more recent method of detecting ultramicroscopic bodies is to employ their power of diffracting the light which falls upon them. They thus become mere point sources of light, but diffraction discs are formed upon the retina of the eye, as in the case of stars the dimensions of which are far too small to subtend an appreciable angle, even with the most powerful telescopic aid.

In the microscope, then, the illuminated ultramicroscopic object merely appears as a star of light. The form of the object is entirely unobserved, its presence only being appreciable when certain conditions are fulfilled. These are that the illumination shall be intense, that the field shall be profoundly dark, and that the objects themselves shall be sufficiently sparsely distributed in the field. It is advantageous, too, to employ those rays which make as small an angle with the illuminating beam as is consistent with other conditions.

To ensure the dark field it is strictly necessary that none of the illuminating light shall, except by diffraction, pass into the objective.

First, we have described in detail the apparatus of Siedentopf and Zsigmondy. In this the light from a narrow slit is focussed in such a way as to pass horizontally through the transparent medium under observation, forming a much diminished image of the slit exactly in the point of view of the microscope. In this image the width of the tape of light producing it corresponds to the length of the slit, and the depth to the width of the slit. The depth of the illuminated region thus becomes, with a knowledge of the diminishing power of the train of lenses, strictly calculable, this being of importance in estimating the number of particles rendered visible in a cubic millimetre. No part of the illuminating beam can, except when diffracted by small particles, pass into the objective. The mean direction of the rays which do so pass will be at right angles to the illuminating beam. The plan has the great advantage that an immersing liquid can be employed in the examination of solids, such as glasses tinted with metals, or of liquids beneath a covering glass. The adjustments must, however, be extremely nice, and require that the whole apparatus should be mounted upon one bank.

The authors have devised a simpler plan of illuminating the subsurface regions of a medium by taking care that incidence with the surface shall be at an angle exceeding the critical angle. To this end a small but intense beam of light is brought from a small arc downwards at an angle of 51° to the vertical. This passes at vertical incidence through the bevelled edge of a glass plate about 1 cm. thick upon the microscope stage. It is then totally reflected upwards by the lower surface towards the upper one.

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Upon this is placed the microscope slide, with an intervening drop of cedar-wood oil, so that total reflection does not occur again until the upper surface of the cover glass is reached, when the ray is again sent downwards and passes away through another bevelled edge. It will be understood that the preparation does not contain air. On this plan no immersion liquid can be employed in the usual place between the cover glass and the objective, but, on the other hand, the rays diffracted by small particles come off from the main beam at angles considerably smaller than a right angle.

Several chapters of the book are devoted to the investigations which have been or can be carried out by these ultramicroscopes, of high interest to many. As examples, we may cite the distribution of silver, gold, and other metal particles in the coloured glasses containing them, and in the hydrosols of such metals; the Brownian movements of ultramicroscopic bodies in colloids, and the translation of such bodies by electric current. Especiallv interesting is the description given of the motions of silver particles in the hydrosol of that metal prepared by the Bredig process of forming a submerged electric arc between silver wires. The particles, below certain dimensions, remain in stable suspension. They are quite ultramicroscopic, but still are capable of diffracting light. When an electric current is passed through the liquid contained in a layer, not too thin, between top and bottom planes of glass, quartz, mica, &c., the microscope being focussed at the middle of the layer, at a point about equally removed from either electrode, the points of light seen move equably in a direction from the kathode to the anode, the speed being proportional to the potential gradient. For one volt per centimetre the speed is about 3·78 μ per second. Above and below this central region, *i.e.* in beds adjoining the top and bottom boundaries, the motion is in the opposite direction, somewhat slower and less equable, and variable with the size of the particles.

If the boundary surfaces are of glass, these inverse beds are each about 25 μ in depth, and if the thickness of the whole layer is diminished until it is only 50 μ, it is these inverse beds which survive, the central one being gradually extinguished. The motion will then be entirely from anode to kathode.

The material of the boundaries affects the depth of the inverse beds, which with quartz is rather less than 2·5 μ, and seems to disappear with gypsum. Mica has much the same effect as glass in this particular.

The particles have such exceedingly small mass that their ultimate velocities in the central region are acquired instantaneously, and if the electrodes are connected with an alternating source of electromotive force, the points of light move backwards and forwards in harmony with the stress through a distance proportional to its mean value and to the period, the constant being sensibly consistent with the speed under uniform stress quoted above. If a three-phase machine is connected with three electrodes, the particles describe closed curves.

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ANCIENT AND MODERN SHIPS.

Ancient and Modern Ships. By Sir George C. V. Holmes, K.C.V.O. Part i., Wooden Sailing-ships. Pp. xv+168. Part ii., The Era of Steam, Iron, and Steel. Pp. xii+219. (London: Printed for His Majesty's Stationery Office by Wyman and Sons, 1906.) Two vols, cloth-bound, price 2*s.* 3*d.* each.

THESE volumes belong to the series of science handbooks issued by the authorities of the Victoria and Albert Museum at South Kensington. The author was for a long period secretary of the Institution of Naval Architects; he is well qualified for the task he has undertaken. Within extremely narrow limits of space (about 400 pages) he has produced a readable account of ancient and modern ships, in which a large amount of trustworthy information has been summarised and admirably illustrated. Although the original intention of these handbooks may have been the assistance and instruction of visitors to the collection of naval models in the museum, they will undoubtedly prove of interest as books of reference to all who are interested in the history of shipbuilding. Their moderate price ought to secure a large circulation.

In the first volume wooden sailing-ships are described. This part of the work was published in 1900, but has been revised and re-issued in company with the larger second part, in which the history of the era of steam, iron, and steel is traced, so far as mercantile ships are concerned. War-ships, considered as fighting machines, are not dealt with, but the influence of peculiarities in their construction upon the development of mercantile shipbuilding is illustrated. Formerly, the naval models at South Kensington included those of war-ships; when the Royal School of Naval Architecture was transferred to Greenwich (more than thirty years ago) the Admiralty also concentrated there its collection of war-ship models. South Kensington retained the mercantile models, and the present collection includes loans from private firms, as well as models which are national property. It is much to be desired that the collection should be made complete and should illustrate adequately the development of the British mercantile marine. If Sir George Holmes's handbooks should increase public interest in the collection and lead to its proper development, a good purpose will have been served. At all events, he has produced a work which will enable laymen to reach an intelligent understanding of the history of shipbuilding and the principles governing the structural arrangements of ships.

Beginning with an admirable account of ancient Egyptian vessels, the author describes boats still existing and to be seen in the Cairo Museum, although they were built nearly 5000 years ago. Ships of the Mediterranean and Red Seas—Phœnician, Greek, Roman, and Venetian—are next dealt with. Another chapter is devoted to the ancient ships of northern Europe, of which specimens have been discovered in Scandinavia in recent years.